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King Abdullah Petroleum Studies and Research Center

Utility-Scale Storage: Sleeping Giant or Mirage?

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About KAPSARC

The King Abdullah Petroleum Studies and Research Center (KAPSARC) is a non-profit global institution dedicated to independent research into energy economics, policy, technology and the environment across all types of energy. KAPSARC's mandate is to advance the understanding of energy challenges and opportunities facing the world today and tomorrow, through unbiased, independent, and high-caliber research for the benefit of society. KAPSARC is located in Riyadh, Saudi Arabia.

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Key Points

The demand for electricity storage is expected to grow significantly in the near and medium term. This growth will be propelled mainly by the increasing number of microgrids, continued renewable energy penetration in the global power sector, progress in electromobility, and technological advancements in the storage sector.

There are four main types of storage technologies available in the market (mechanical, electrical, electrochemical, and thermal). Electrochemical storage is expected to evolve as the most prevalent and impactful storage technology in the coming decade.

By 2025, the electrochemical storage market is expected to reach $4 billion, with lithium-ion technology holding a share of about 22%. In addition to the advancements occurring in battery technology, additional cost reductions are likely to stem from efficiency gains within the battery supply chain.

Storage is a unique technology. Energy storage systems can be deployed anywhere in the power generation supply chain, i.e., in the generation, transmission, or distribution segments. Storage can also compete in energy, capacity, and ancillary services markets. One can see from this why regulating storage is not straightforward.

Currently, there is no market sophisticated enough to accommodate storage and all its capabilities. Most storage projects have been financed through equity and government grants. The small number of ‘data-points’ makes borrowing difficult.

Several countries and utilities have taken progressive steps to enable further storage deployment. These include allowing storage to compete in all markets, revising interconnection processes to include storage, encouraging hybridization, and rewarding performance (like faster response and ramping).

There is reasonable evidence to be optimistic that storage technologies will deliver on their potential and be important contenders in the future of global energy.

Background to the Workshop

The Kingdom of Saudi Arabia, among other countries, has ambitious plans to install a significant amount of renewable capacity by 2040. A high share of renewable generation in the power system can, however, result in grid instabilities. Energy storage technology is one option that could address these challenges, being an enabler of increased renewable generation in the power sector.

In addition to playing a role in stabilizing the grid by complementing renewables, energy storage can also contribute to environmental goals, including supporting the concept of the 'circular carbon economy,' as proposed by Saudi Arabia in its presidency of the G20. The circular carbon economy comprises four principles for managing carbon emissions: reduce, reuse, recycle and remove. Energy storage can contribute to 'reduce,' and it can maximize renewable deployment. Storage was not considered cost competitive in the past, but several market and technological advancements are now contributing to making utility-scale storage more competitive.

Energy storage can be deployed at the generation, transmission, and distribution segments of the energy supply chain. It can also compete in energy, capacity and ancillary markets. This versatility makes energy storage difficult to regulate. These regulatory challenges, coupled with legal and financial implications, stand in the way of wider and speedier storage deployment. Notably, the types of challenges facing energy storage in vertically integrated utilities would differ from those faced in a market environment.

The above is a sample of the numerous considerations relating to energy storage deployment. This workshop was arranged to discuss these topics and formulate a better understanding of how energy storage might evolve.

Storage Technologies and Costs

The demand for electricity storage is expected to grow significantly in the near and medium term. This growth will be propelled mainly by the increasing number of micro-grids, continued renewable energy penetration in the global power sector, progress in electromobility, and the technological advancements in the storage sector itself. Renewable plans will probably be the biggest drivers of energy storage demand. According to the International Renewable Energy Agency's (IRENA's) Transforming Energy Scenario, by 2050, over 70% of the needed 20,000 gigawatts (GW) of global system capacity should come from solar and wind. With such a large share of renewables in the energy mix, grid flexibility becomes a concern, and storage is an important contender in enabling these ambitions.

There are four main types of storage technologies available in the market (mechanical, electrical, electrochemical, and thermal). Electrochemical storage is expected to become the most prevalent and impactful storage technology in the coming decade. Within the electrochemical realm, lithium-ion (Li-ion), lead-acid (LA), and redox flow are the dominant chemistries. The current levelized cost of storage (LCOS) values for these technologies are not competitive for all applications across all geographies. For example, the median LCOS value for Li-ion and LA batteries are around 0.45 euros per kilowatthour (EUR/kWh) and 0.25 EUR/kWh, respectively. However, technological advancements in the industry are expected to bring these costs down. Li-ion battery LCOS, in particular, is projected to drop to approximately 0.10 EUR/kWh.

The improvements witnessed in energy storage technologies are primarily attributed to the private sector's research and development efforts. Tesla has bold targets to produce an electric vehicle costing $25,000 in two to three years and to increase the range of its vehicles by nearly 50%. Quantum Scape claims that energy densities as high as 500 watthours per kilogram (Wh/kg) would be possible with their next-generation lithium-metal technology (current densities are around 300 Wh/kg). By 2025, the electrochemical storage market is expected to reach $4 billion, with Li-ion technologies holding a share of about 22%. While the drivers for energy storage growth are not necessarily restricted to Li-ion, synergies in the development of Li-ion batteries for electric vehicle (EV) industries and stationary applications will push the scale of Li-ion deployment more than other technologies.

In addition to the advancements occurring in battery technologies, additional cost reductions are likely to stem from efficiency gains within the battery supply chain. The energy storage supply chain is complex and involves several types of stakeholders. With this multiplicity, we see that there are standardization challenges and constant shifts in material usage. Coupling these factors with raw material mining challenges, it comes as no surprise that there is a wide range of capital costs in the electricity storage industry. As the supply and value chains of storage mature, the upscaling of manufacturing will result in cost reductions – similar to that experienced by the solar photovoltaic generation (PV) industry nearly 20 years ago.

As storage technologies continue to evolve, business models will also continue evolving. It is worth noting that it is easier to follow the evolution of residential-scale storage systems. Compared with utility-scale storage, residential-scale storage has been deployed more quickly because it faces fewer technical and regulatory constraints. We will also likely see the EV battery industry driving developments in large-scale stationary storage. Many experts foresee vehicle-to-grid supply playing a significant role in future grids – perhaps even a bigger role than stationary batteries currently play.

Regulating and Financing Storage

Similar to the developments occurring in energy storage technologies, regulatory and financial developments are also evolving. However, these developments are not as fast and progressive as investors wish. Regulating and financing utility-scale storage are considered relatively new areas, and their rules and norms are being written and established as they develop.

Energy storage is a unique technology. Energy storage systems can be deployed anywhere in the power generation supply chain, i.e., in the generation, transmission, or distribution segments. Energy storage can also provide more than one service in each segment, and more than one service in different segments simultaneously. The latter is known as value-stacking. With this versatility, storage technologies can compete in energy, capacity, and ancillary service markets. Another unique property of energy storage is that it can provide energy to the grid and also withdraws energy from the grid to charge itself. In other words, storage acts both as an energy provider and a load. Given these characteristics, one can see why regulating storage is not a straightforward task.

No market is currently sophisticated enough to properly accommodate and value energy storage and its manifold capabilities. In the markets where energy storage operates, revenue is restricted to one of a few services, such as, for example, energy, capacity, or regulation services. However, there are currently no markets for services like avoiding thermal generation starts, increasing system efficiency, ramping/following, and black starts. Hence, storage providers cannot be compensated for any of these services. Although storage can provide a number of services across the power generation supply chain, it will not necessarily receive compensation for these services due to the lack of markets for them or regulatory restrictions.

Further, system operators have been dealing with legacy generators for decades, and the inherited regulations offer limited revenue streams to reward performance.

Renewable energy has typically been deployed using an independent power producer (IPP) model and a power purchase agreement (PPA). Should energy storage adopt the same operating models? Or should energy be directly procured? Given the few global energy storage projects, the answer to this question does not seem to be clear cut. Part of the ambiguity is created by the insufficient clarity on long-term revenues that would result from deploying energy storage.

The complexity of energy storage deployment and financing includes how the storage is used. The lifetimes of storage devices depend heavily on their operation. Moreover, the warranties granted by storage developers contain strict clauses on the operation of the storage devices. These two observations, which do not apply to solar PV plants for example, can also repel investors. In light of the above technological and regulatory challenges, we see that most storage projects have been financed through equity and government grants. The few data points for past projects makes financing difficult to obtain. As with other power generation projects, lenders look at the credit worthiness of the utility and the political stability of the host government. In the near term, and until markets evolve and regulations change, vertically integrated utilities provide a more attractive environment for storage, as this type of utility will be able to capture all the benefits that energy storage would bestow upon the network, irrespective of where storage is deployed.

Despite the hindrances mentioned above, several countries and utilities have taken progressive steps to enable further energy storage deployment.

Among these steps are allowing energy storage to compete in all markets, revising interconnection processes to include storage, encouraging hybridization, setting procurement targets for renewable and storage projects, offering subsidies and rebates through green energy financing programs, and rewarding performance (like faster response times and ramping). These tools have been primarily implemented in the United States, Australia, Germany, and Italy. Examples include the 100-megawatt (MW) Li-ion battery project in South Australia, which was integrated with renewable generation and reduced load-shedding events. This project resulted in AUD$150 million of consumer savings in the first two years of operation. Similarly, a 38 MW storage facility in the Campania region of Italy was able to relax network congestion and defer transmission investments.

Although many challenges stand in the way of energy storage deployment, they do not appear to be unsolvable or insurmountable. In fact, renewables have faced similar challenges over the past 20 years. There is reasonable evidence to be optimistic that energy storage will deliver on its potential and be an important part of the future of global energy.

About the Workshop

This workshop was held virtually on November 24, 2020. It brought together the following four experts to discuss key opportunities and challenges related to energy storage deployment:

List of participants

Hesham Fageeh – Consultant in the Energy, Utilities, and Resources Practice, Strategy& Middle East

Oliver Irwin – Project Finance Partner, Bracewell (U.K.) LLP

Vatche Kourkejian – Partner in the Energy and Industrial Practice, Roland Berger

Michael Taylor – Senior Energy Analyst, International Renewable Energy Agency (IRENA)

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About the Team

Amro Elshurafa

Amro is a Research Fellow working on energy transitions. His research interests include power system modeling, solar photovoltaic (PV) techno-economics, and hybrid microgrid design and optimization. He has led and executed several national energy modeling efforts at the distributed- and utility-scale. Credited with 40+ papers and several patents, he holds a Ph.D. in electrical engineering and an MBA in finance.

About the Project

Energy Transitions is primarily focused on the switch to low-carbon energy sources in the power sector. This translates into the increased use of renewables and gas instead of coal for power generation. The increased use of intermittent renewables, however, creates demand for more flexible generation, which today is mostly gas-fired generation. The increased use of natural gas places upward pressure on global gas prices, which in turn affects the underlying economics of the other fuels used in the power sector.

In the future, given the technological advancements and downward cost trajectories of energy storage, it could help mitigate large fluctuations in grid supply. However, there remain several technological and regulatory challenges facing energy storage. The energy transition could therefore have ripple effects on the economics of the power sector. This project is timely and relevant for a number of key energy stakeholders in the Kingdom, including the Saudi Electricity Company, the Regulator, and The Ministry of Energy.

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